University of Alberta

The effect of interference on false recognition in younger and older adults

by

Barbara Dawn Waldie

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment

of the

requirements for the degree of Master of Science

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ABSTRACT

This experiment examined age-related increases in false memory errors in the Deese-Roediger-McDermott paradigm (Roediger & McDermott, 1995). This was accomplished by evaluating the impact of interference at time of study on later memory accuracy. To this end, related and unrelated distractor words were presented with the to-be-studied lists. Three behavioral measures (recognition accuracy, naming times and recognition response times) were included to assess the impact of distraction. The addition of unrelated words as interference did not impact the characteristic false memory effect – older adults were more likely to incorrectly recognize the critical target than were young adults. However, presentation of the critical target as a distractor mid-way through the list presentation negated this typical age difference. Naming times and recognition response times also indicated that presentation of the critical target as a distractor had a unique impact on performance. These results highlight the importance of efficient inhibitory control in memory accuracy tasks, consistent with the inhibitory deficit theory of aging.

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INTRODUCTION

Investigations seeking to understand the intricacies of human memory have led to advances in the experimental tools available to examine memory processes. One such tool, which has gained considerable notoriety in the past few years because of its ability to reliably induce false memories under a number of experimental manipulations, is the false memory paradigm, or the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995). Within this paradigm, participants are instructed to study lists of semantically related words for subsequent recall or recognition testing. In particular, the items in each word list are the highest semantic associates to a non-presented, critical target word. For example, the words *thread, pin, eye, sewing, sharp* all converge on the non-presented critical target *needle*. The false memory effect is the incorrect recall or recognition of this non-presented, critical target word (hereafter referred to as the critical target; see Roediger, McDermott & Robinson, 1998 for a review). This paradigm is useful not only for examining memory accuracy in healthy young adults, but it is also instrumental in understanding changes in memory processes associated with aging, brain injury and disease that may alter accessibility to and accuracy of retrieved memories.

Cognitive Aging

The main purpose of the experiment reported here is to better understand the nature of age-related changes in daily cognitive processes by investigating age-related differences in susceptibility to false memory errors in the DRM paradigm. Older adults are known to show performance decrements in a variety of cognitive domains, with younger adults typically out-performing older adults (e.g. Park, Anderson,

Lautenschlager & Earles, 1996). Documented deficits include memory, planning and problem solving, comprehension, attention, and processing speed, to name a few.

Current attempts to account for age-related differences in cognitive functioning indicate that the picture is not nearly as straightforward, nor as bleak, as the previous statements may suggest. First of all, increasing age is associated with increased heterogeneity (Baltes & Baltes, 1990). That is, aging is characterized by large inter-individual variability in performance and in the rate and extent of change. Such individuality means that some individuals show large amounts of change on a range of tasks, whereas some show little, if any, change and others yet may show decrements on only selected tasks. Similarly, each of the cognitive domains identified above can be further divided into more specific cognitive abilities. Within each of these domains there may be large variability in the extent of age-related differences typically documented in these cognitive abilities. One such example is in the memory domain. Although older adults typically show generalized decreased memory performance, the deficits tend to be greater for episodic memory tasks (memory for specific events) than for either semantic or procedural memory tasks.

The precise nature and demands of the tasks used to assess cognitive ability also have a significant impact on the degree of age-related deficits observed. Using less effortful tasks and increasing the availability of environmental supports both attenuate the absolute size of age-related deficits. For example, recognition memory tasks are typically less problematic for older adults than are free recall tasks. In addition, assessing cognitive function with tasks based on skills or domains in which individuals are highly familiar and have a high degree of expertise also reduces age-related differences. In such

situations, it is understood that individuals use cumulative life experience or personal strategies to compensate for any apparent deficits. One common example is Salthouse's (1984) demonstration that expert typists are able to type as quickly and accurately as younger typists when able to utilize their superior scanning strategies.

Even though the above findings account for some of the age-related decrements in cognitive functioning on specific tasks or in specific situations, there still exists a fundamental trend in the cognitive aging literature that increasing age is associated with decreasing cognitive performance. In order to make sense of this literature and to account for the performance patterns documented therein, many researchers are taking the approach of looking across tasks and cognitive domains to identify the general factors underlying performance. For example, one metaphor often used to explain age-related differences is a cognitive resource metaphor. According to this metaphor, it is envisioned that all cognitive tasks draw upon and utilize space or time from a finite pool of resources. Furthermore, with increasing chronological age there is a corresponding decrease in capacity or efficiency within this resource pool. This is reflected as decreased on-line ability to process information (Park, 1999).

Although such a perspective is beneficial in conceptualizing age-related changes in cognition, further clarification of the specific mechanisms underlying this reduction in on-line resources is needed. To this end, four hypotheses have been proposed in the last two decades. Competing approaches include the working memory capacity hypothesis (Craik & Byrd, 1982), the speed of processing theory (Salthouse, 1996), the sensory deficit hypothesis (Lindenberger & Baltes, 1994), and the inhibitory deficit theory (Hasher & Zacks, 1988). Although often presented as independent explanations, it is

likely that a comprehensive explanation of cognitive aging will arise from a combination of these approaches.

Explanatory Hypotheses of Cognitive Aging

The first hypothesis is the working memory capacity hypothesis (Craik & Byrd, 1982). This hypothesis conceptualizes working memory as the amount of on-line resources available to process, store and retrieve information at a given moment. It further postulates that associated with increasing age there is a decrease in the amount of resources available to process or store information. Due to reductions in working memory capacity, older adults are limited in their ability to perform mental tasks compared to younger adults. Within this hypothesis there is greater emphasis placed on processing resources rather than storage functions. Therefore, the extent of age-related deficits observed is relative to the amount of information that needs to be simultaneously processed. Tasks that require significant amounts of processing resources will show greater age differences than less effortful tasks. For example, tasks requiring self-initiated encoding and retrieval processes, such as generating inferences or novel connections among items are viewed to require more processing resources and demonstrate larger performance declines associated with age.

Alternatively, the theory of generalized slowing of information processing speed (Salthouse, 1996) suggests that increases in the time required to perform mental operations can account for much of the age-related variance in performance. The rationale behind this theory is essentially that if older adults processes information more slowly then some information may be lost from working memory before an appropriate output is generated (the limited time mechanism) or before later computations based on

earlier information can be processed (the simultaneity mechanism). Salthouse cites numerous studies demonstrating that increasing age is associated with decreased processing speed.

Most recently, Lindenberger and Baltes (1994) have proposed the sensory deficit hypothesis. This hypothesis focuses on the correlation between declines in auditory and visual domains and cognitive performance. For example, they found that together visual and auditory functioning account for 93% of the age-related differences in intelligence. Sensory function may act as a physiological marker, such that common physiological changes associated with increasing age may similarly account for decreased sensory functioning and cognitive performance. Alternatively, as a result of decreased sensory functioning, more effort may be allocated into simply decoding the incoming message, leaving fewer resources for cognition.

The fourth hypothesis, the inhibitory deficit theory, postulates that deficits in inhibitory control may account for age-related performance deficits (Hasher & Zacks, 1988; Kwong See & Ryan, 1995; Persad, Abeles, Zacks, & Denburg 2002). Hasher & Zacks argue that any mechanism that effectively reduces the capacity of working memory may be responsible for age-related decrements. Therefore, decreased capacity is not due to reductions in the amount of information that can be processed and stored in working memory at one time, but rather it is indirectly due to an increase in the amount of irrelevant information entering into working memory. This has the effect of reducing the capacity of useable resources.

Inhibitory control is hypothesized to aid in regulating the contents and efficiency of working memory. It is a key component of a wide range of cognitive activities

including language, comprehension, speech patterns, selective attention and memory retrieval (Hasher & Zacks, 1988; Kwong See & Ryan, 1995). With age, inhibition may become compromised such that it is more difficult to effectively inhibit focusing on or directing attention to marginally relevant, irrelevant and/or distracting stimuli and thoughts (Kane, Hasher, Stotzfus, Zacks & Connelly, 1994; Li, Hasher, Jonas, Rahhal & May, 1998; McDowd & Oseas-Kreger, 1991). Furthermore, once irrelevant information enters working memory, older adults may have more difficulty disengaging attention from this stimulus. Therefore, according to the inhibitory deficit theory, the capacity of working memory appears to be reduced due to an increase in irrelevant information that subsequently interferes with the processing of goal-directed material. Although the inhibitory deficit theory has received mixed reviews (Burke, 1997; McDowd, 1997), it remains a reliable theory in terms of its ability to provide a comprehensive account of the cognitive aging literature.

Supporting evidence for an age-related decline in inhibition comes from a range of empirical studies including but not limited to Stroop interference (e.g. Kwong See & Ryan, 1995; Spieler, Balota & Faust, 1996), negative priming (McDowd & Oseas-Kreger, 1991) and the fan effect (Gerard Zacks, Hasher, & Radvansky, 1991). Inhibitory competence in the Stroop task is inferred from older adults showing a greater degree of interference in the word naming speed than in the color naming speed condition. In the experimental condition (word naming), participants read aloud color words that are printed in an incongruent ink color, whereas in the baseline condition (color naming) they simply say aloud the ink color of a series of x's. The extent of interference is the difference between word naming speed and color naming speed. Typically this difference

is significantly greater for older adults than for younger adults. An increase in Stroop interference is indicative of reduced ability to inhibit automatic processing of ink color in the word naming condition. In addition, Kwong See & Ryan found that Stroop interference was a significant predictor of language performance.

Similarly, in the negative priming paradigm, decreased inhibitory efficiency is inferred from finding that older adults are equally fast to identify a target that was a distractor in the preceding item as they are to identify a randomly generated target (unprimed target; McDowd & Oseas-Kreger, 1991). If the older adults had successfully inhibited an item when it appeared as a distractor, then they should have taken longer to identify the item when it was subsequently presented as the target (negative priming). This is the pattern of results seen in young adults. Lastly, in fan effect experiments, the number of errors and the response times in a recognition test are taken as measures of inhibitory control. Participants make speeded verification judgments for test sentences based on a series of target facts learned about a number of topics. Gerard et al. (1991) found that performance on the verification task depended on the 'fan size' of the learned target facts. That is, the larger the fan size, or the number of facts to be learned, the longer the response times and the greater the number of errors. Both these variables differentially increased for older adults relative to young adults. Based on such findings, age-related changes in inhibition have been proposed to underlie the age-related changes in attention and consequently may be responsible for a variety of behaviors typically associated with age-related declines in cognitive functioning (Hasher & Zacks, 1988).

False Memories and Cognitive Aging

In order for these hypotheses to be seen as viable explanatory options, they must be able to account for and stand up to empirical evidence. The purpose of the experiment reported here is to evaluate the ability of the inhibitory deficit theory to explain age-related differences in memory distortions in general, and in the DRM paradigm in particular.

Age-related susceptibility to memory distortions or illusions are of particular interest as they are well documented in a variety of paradigms, in both laboratory and real-life settings. In the DRM paradigm this is evident when false memory is measured relative to veridical memory performance (e.g., Norman & Schacter, 1997; Tun Wingfield, & Blanchard, 1998; Waldie & Kwong See, in press). This is true whether the words are presented orally or visually and in fact, the presentation of categorized pictures increases the age difference effect size and produces more reliable results (Koutstaal, Schacter, Galluccio, & Stofer, 1999). Memory distortions have been demonstrated in other experimental paradigms. For example, older adults are more likely to recollect witnessing events that did not occur, known as the misinformation effect (Cohen & Faulkner, 1989). In experiment 2, Cohen and Faulkner utilized a typical eyewitness testimony/misinformation paradigm: the participants first watched a short video of an event, read a written passage of the same event, and then answered questions regarding the short video. For half the participants, the passage they read was completely correct with respect to the video, but for the other half the passage contained critical errors. The participant was unaware of these errors. In the recognition test, the older adults were more likely to be misled by the incorrect information than were the young adults.

In a series of experiments with the false fame paradigm, Jacoby (e.g. Dywan & Jacoby, 1990) has also demonstrated that older adults are more susceptible to memory errors. In this task subjects are first shown a series of names of non-famous people and are instructed to read these names out loud as quickly and accurately as possible. Following a brief delay they were shown another set of names and asked to indicate whether these names were famous or non-famous. Unknown to the subjects, some of these names overlapped with the first set of names. Interestingly, the older adults were more likely to judge the repeated non-famous names as famous people in this subsequent presentation than were the young adults. These three paradigms repeatedly demonstrate that accurately remembering and discriminating between events that occurred from those that did not occur is more problematic for older adults. This is inferred from finding an increase in memory errors in older adults relative to young adults.

Explaining why it is that older adults' consistently show increased susceptibility to memory distortion is the topic of much empirical and theoretical debate. Resolution of this debate will be favorable for developing compensatory strategies for improving memory accuracy as well as strengthening our understanding of the role of cognitive mechanisms in accounting for age-related change. We will briefly review some of the common explanations and approaches towards understanding false memory errors of which the inhibitory deficit theory is but one explanation. First however, we will overview a basic interpretation of the general DRM paradigm. Once again, the specific effect that we are attempting to substantiate and explain is the tendency for older adults to remember fewer veridical items than do young adults, but to be equally or more likely to falsely recognize the non-presented critical target items as younger adults.

Explanations of the False Memory Effect

Spreading activation and false memories. The original Roediger and McDermott (1995) paper suggested that one way to account for their finding was the Implicit Associative Response, which emphasized the activation of associated words within the semantic network (Underwood, 1965). During the study phase, individual words presented to the participant lead to a corresponding node to become activated within the semantic network. Based on the theory of spreading activation, all word or concept nodes are interconnected with semantically related word or concept nodes (Collins & Loftus, 1975). Activation is presumed to spread automatically between these related nodes, briefly highlighting non-presented words or concepts. In the DRM paradigm, the words in each list were specifically chosen because of their high association to the critical target. Therefore, activation from the presentation of the list items should converge on and prime the critical target. As items are encountered or recalled during the test phase, it is likely that automatic spreading activation once again will create spurious activation of the related critical targets. This interpretation emphasizes the importance of the integrity of the semantic network and the spread of activation in this paradigm, laying the framework within which we can understand the postulated explanations for age-related differences in memory accuracy.

Multiple lines of research implicate the importance of activation strength in the production of false memories for the critical target. For instance, increasing the number of word associates presented from 3 to 15 increases the probability of false recall but decreases the probability of veridical recall in young adults (Robinson & Roediger, 1997). Further support comes from recent work by Roediger, Watson, McDermott and

Gallo (2001). A multiple regression analysis indicated that, of eight factors, the backward associative strength of the list items to the critical target was the best predictor of false recall of the target word (see also McEvoy, Nelson & Komatsu, 1999). Strengthening the activation of related concepts by emphasizing the relationship between the list words increases the probability of false memories (Buchanan, Brown, Cabeza & Maitson, 1999; Mather, Henkel, & Johnson, 1997; Read, 1997).

Gist information and false memories. Although automatic spreading activation to the critical target is an important determiner of the false memory effect, it is likely not the only piece to the puzzle. Other interpretations have focussed on the encoding and retrieval of this activated information by younger and older adults. One such explanation emphasizes the contribution of gist or general similarity information to response choices (Kensinger & Schacter, 1999; Koutstaal, Schacter, & Brenner, 2001; Tun et al, 1998). This may occur at encoding, retrieval or reflect an interaction between the two. For example, there is evidence that older adults focus on the general characteristics or global semantic association of the studied items instead of attending to the item-specific details or distinctive information at encoding (e.g. Koutstaal, et al, 1999)

This may be particularly relevant in the DRM paradigm because of the conceptual similarity of the study items. Furthermore, the feature attributes of the critical target items overlap considerably with the studied items. Therefore, increased reliance on gist information of category/semantic list knowledge would facilitate recall or recognition of the target items. Failure to encode item-specific details may result in the memory trace having insufficient diagnostic information to separate studied from non-studied items. This pattern of increased reliance on gist processing has been found with words and

pictures (Schacter, Israel & Racine, 1998; Tun et al, 1998). Encouraging the encoding of distinctive information at study decreases the false memory effect in older and younger adults, although the age difference remains (Koutstaal, et al, 1999; Koutstaal, et al, 2001; Schacter, Israel & Racine, 1998). Reducing study duration and thereby reducing opportunities for distinctive or elaborate encoding of specific items increases false recall of the target item for young adults (McDermott & Watson, 2001).

Alternatively, an increased reliance on the gist (i.e. fuzzy trace theory, Reyna & Brainerd, 1995) or general similarity of information (Hintzman, 1988) on memory retrieval may also account for the empirical results (Kensinger & Schacter, 1999). For example, readily available knowledge of the general semantic information of the studied lists may lead older adults to call upon few item-specific details of the studied items to make recognition decisions. Although these item-specific memories appear to be degraded in older adults, through encouragement these details can be retrieved. Since item-specific memories are thought to oppose, in some way, the strength of the gist memories, increasing awareness of item-specific details logically increases memory accuracy by decreasing reliance on gist memory (Koutstaal et al, 1999). This suggests that older adults evaluate test items according to their general similarity to the studied items rather than focus on the discriminating information. However, the paucity of encoded item-specific information or its use, does not fully account for increased susceptibility to false memories. Even older adults matched to young adults on veridical memory performance continue to show increased false recognition rates (Balota et al, 1999; Koutstaal, et al, 2001).

Older adults may therefore refrain from critically evaluating the test items for discriminating details and instead rely on general similarity information. Some researchers have likened this to age-related differences on familiarity-based responding in contrast to conscious recollection in completing recognition judgements (Jennings & Jacoby, 1993; Koutstaal,et al, 2001). According to this framework, a combination of item-specific or consciously recollected information along with a generalized feeling of familiarity to the stimuli is hypothesized to facilitate recognition judgments. Recollective judgments are presumed to demand more controlled or attentive processes, whereas familiarity judgments are presumed to be fast and automatic. Hypothetically, studied items would evoke both feelings of conscious recollection and a generalized feeling of familiarity resulting in positively judging the item as one that had been presented. On the other hand, false recognition may reflect only the less attention demanding analysis afforded to feelings of familiarity, as there would be no recollective trace for items that were not previously presented. Coincident with evidence that older adults' experience declines in attention demanding controlled processing, it is logical that familiarity may drive responding more than recollection in older adults. In fact it has been suggested that older adults may find it particularly difficult to avoid responding on the basis of familiarity (Koutstaal, et al, 2001). Therefore, one would expect to see a decrease in veridical memory and an increase in false memory with increasing age, as the general similarity trace or familiarity is more influential and there is less opposition from item-specific memory.

Source monitoring and false memories. Explanations based on the source-monitoring framework also highlight the decreased likelihood that older adults routinely

engage in effortful, strategically driven retrieval. Johnson, Hashtroudi & Lindsay (1993) define source-monitoring as "the set of processes involved in making attributions about the origins of memories, knowledge and beliefs". They go on to propose that, according to their framework, source monitoring depends on the characteristics of memories in combination with judgment processes. Depending on the qualitative characteristics that are available (the spatial, temporal, perceptual or social context of the event), source decisions can be made relatively rapidly or may involve more strategic, deliberative processes. (Johnson, et al.). Source attributions help to guide decisions regarding test items. Therefore, false recognition may arise due to the high degree of qualitative similarity between studied items and critical targets and may also reflect the extent to which individuals take advantage of the differences between the remembered characteristics of these items to guide their judgment (Norman & Schacter, 1997). Failing to critically evaluate recognition items to take full advantage of any qualitative differences that might exist between studied and non-studied items may lead to incorrect responding. To further understand the influence of source-monitoring in the DRM paradigm, Norman and Schacter asked young and older adults to explain their response choices. The goal was to identify the type of information on which their judgments were based. Both groups recalled a variety of information with memory for sensory and contextual details being the best discriminator between studied items and critical targets overall. However, these variables discriminated less well for older adults. Their interpretation suggested that increased vulnerability to source misattributions is either due to older adults failure to remember perceptual and contextual details or it is due to older adults failure to engage in careful monitoring of the available information. The diagnostic

information used by older adults is less effective than that used by younger adults to accurately discriminate studied items from non-studied yet highly familiar items.

Response criterion and false memories. Another explanation receiving some support in this literature is that of older adults' use of more liberal and lenient response criteria (Kensinger & Schacter, 1999). The quality of stored memory representations may contribute to performance in a number of ways, with one influence being on response criteria. If younger adults have more distinctive or recollective material available, they may in turn demand more from a situation or item before they willingly classify it as 'old' (or 'yes - I remember studying it') (Koutstaal et al., 1999). Without access to this distinctive information, older adults may be more lenient in classifying items as 'old'. Alternatively, older adults may be more likely to respond 'old' on a recognition test than are younger adults possibly due to personal awareness or concern over declining memory abilities.

Inhibitory control and false memories. Although the above explanations can account for the performance pattern seen in older adults, more precise identification of the underlying mechanisms is needed. For example, it is unclear from these explanations why it is that older adults might be more likely to encode or retrieve general similarity information instead of item-specific details. A common theme to these explanations is the involvement of both automatic and effortful cognitive processing in memory accuracy tasks. The pattern of results presented suggests that automatic, familiarity-based processes, which essentially remain unaltered with age, carry more weight in memory accuracy performance in older adults than younger adults due to declines in the ability of older adults to engage in attention-demanding strategic processing. Therefore, age-related

deficits in attention may underlie the age-related changes in performance in the DRM paradigm.

Specifically regarding false memory effects, recent neuroimaging research and case histories with older adults and individuals with brain damage provide evidence supporting the hypothesis of attention and the corresponding role of frontal lobe functioning as possible mechanisms in memory accuracy (Schacter, Reiman, et al., 1996). For example, Schacter, Curran, Galluccio, Milberg and Bates (1996) detail the case of one individual suffering brain injury to the right frontal lobe who demonstrated very high levels of false recognition on a variety of tasks. Similarly, amnesic individuals show decreased veridical memory as well as low levels of false memory (Schacter, Verfaellie & Pradere, 1996). Frontal lobe functioning is critical to performing attentionally demanding search and retrieval tasks. Norman and Shallice (1986, as cited in Zacks, Hasher, & Li, 2000) proposed of a "supervisory attentional system" which is a limited-capacity mechanism, presumably localized in the frontal lobes and is involved in the strategic control of processing information. Therefore, changes in underlying neural systems may produce breakdowns in attentional selection processes, which will in turn negatively impact both the richness of the encoded memory and the ability to attend to different sources of activated information at retrieval (Balota, Burgess, Cortese & Adams, 2002). This supports the suggestion that older adults are less likely to engage in more effortful strategies, which require more attentional control or resources, and instead respond on the basis of familiarity or generally similar information.

The motivation behind the experiment reported here was to further isolate the influence of attentional control mechanisms in the DRM paradigm (Balota, et al., 1999;

Watson, Balota, & Sergent-Marshall, 2001). Selective attention was of particular interest. Selective attention enables organisms to actively attend to and process stimuli relevant to the task at hand while suppressing or inhibiting the processing of irrelevant or distracting information (Tipper, 1985). Specifically, we were interested in examining whether differences in susceptibility to false memory errors could be explained by age-related deficits in inhibition or inhibitory control during the study phase, as previous work in our lab has indicated (Waldie & Kwong See, in press). In that project, we used the DRM paradigm to examine free recall and recognition performance in young adults, older adults and individuals with Alzheimer's Disease (AD). In comparison to younger adults, the older adults remembered fewer studied items but falsely remembered more critical targets. Similar to the normal older adults, individuals with AD showed increased susceptibility to false recognition of critical targets and test items that were weakly related to the studied items. An argument based on the inhibitory deficit theory was proposed to account for this pattern of results.

Specifically, decreased inhibitory control may translate into reduced ability to ignore the critical target and other non-presented words associated to the study list. According to the theory of spreading activation, activation is assumed to spread from the studied items to related items, causing spurious activation of these related items. Any items that have become activated beyond a minimum threshold level would be assumed to gain access to working memory. Due to reduced inhibitory control, it is proposed that more items will have surpassed this threshold level for older adults and individuals with AD. In comparison, young adults would likely have fewer items accessing working memory and these items would likely possess higher levels of activation. Furthermore,

once these items have accessed working memory space, it may be more difficult for older adults and individuals with AD to suppress and remove the non-studied items from working memory, also due to reduced inhibitory efficiency. Similar to the fan effect, the widespread activation of studied and non-studied items may result in more variability in trace strength for individual items between young and older adults. For example, for the older adults, this might be attenuation in the usual trace strength difference between studied and non-studied items. It would be expected that discrimination between old and new items during the test phase would be more problematic for the older adults. The literature reviewed above implicating attentional control mechanisms as influential to performance in the DRM paradigm further supports this rationale.

Despite suggestions in the literature that inhibitory efficiency is important in the DRM paradigm, no direct evidence either supports or refutes this claim (Schacter, Koutstaal & Norman, 1997; Tun et al., 1998). Although both Balota's results (e.g. Balota et al., 1999) and our own are suggestive of an inhibitory control argument, direct testing of this claim is needed to substantiate our position and clarify the issue. The strategy implemented was to attempt to simulate the performance of older adults in younger adults by adding interference during the study phase. The addition of interference at study would enable us to the measure the extent to which distracting information is successfully inhibited or ignored.

Measuring inhibition in the DRM paradigm

To clearly implicate inhibitory control mechanisms we measured on-line processing of words during the study and test phases of a false memory task modeled after Roediger and McDermott (1995). In the present study, young adults and older adults

read aloud lists of semantically related words (Appendix A). Derived measures of interference were used to assess the efficiency of young and older adults to inhibit the processing of irrelevant information. Presenting distractor items during the study phase was meant to increase the amount of irrelevant information to be ignored. Inclusion of these items was expected to increase the demands on inhibitory processes. Increased task demands were hypothesized to make it more difficult to inhibit spurious activation of the target item than in the standard DRM paradigm. In each instance, the studied list words were to be read aloud and the distractor items were always to be ignored.

The amount and type of interference were manipulated in four study conditions. In the first condition, the no distractor condition, only the list words were displayed on the screen (Appendix B, Figure 1). In the three other conditions participants saw two words simultaneously, the study list word and a distractor item, identified by color. The type of distracting information appearing with the studied list word was manipulated in each case. In the second condition, the baseline control condition, the distractor item was always an unrelated word (Appendix B, Figure 2). The no distractor condition compared to the baseline condition provides an indication of the overall effect of general interference on task performance.

To further implicate build-up and/or endurance of activation of the critical target as underlying the observed age-related difference, two final conditions were added. The third condition was the Critical-6 condition (Appendix B, Figure 3). In this condition the critical target item was presented as a distractor, paired with the sixth studied item. Unrelated distractors were paired with all other studied words in the list. For example, *needle* is the target item for the list containing the words thread, pin, eye, sewing, etc. and

would appear as the distractor paired with the sixth list word. The fourth and final condition, the Critical-12 condition, was similar to the Critical-6 condition except that the target item was paired with the 12th list word instead of the 6th word (Appendix B, Figure 4). The Critical-6 and Critical-12 conditions each compared to the baseline control condition provide information regarding the distraction of the target item which is an indicator of its level of activation (Appendix B, Figure 5).

The primary measure of interest is in the comparison between young and older adults. Therefore, in each treatment condition we compared word naming times (hereafter referred to simply as naming times) during the study phase, as well as response accuracy (correct and false recognition) and response time in the recognition test phase between the two groups.

HYPOTHESES

Interference and Naming Times

A measure of general interference was obtained by comparing the baseline control condition to the no distractor condition. In comparing the naming times for the younger and older adults we expected an age difference favoring the young adults (e.g. Salthouse, 1996). We also expected to see longer naming times in the baseline control condition compared to the no distractor condition. This would indicate that distracting information is interfering with processing of the list items. In addition, this interference effect was expected to be differentially larger in older adults (Tipper, 1991). That is, if both groups continue to process the information in the same manner, but age-related changes result in decreased inhibitory efficiency in older adults, then they should exhibit increased interference effects.

The inclusion of the target item as a distractor in the 6th and 12th positions was to assess the effectiveness with which young and older adults inhibit processing or thinking of this item during study. As previously discussed, the critical target becomes activated during presentation of the list items through spreading activation from the studied list items. However, as this is not an item to be remembered, activation of this node should be inhibited. To measure the amount of interference associated with presentation of the target items as a distractor we compared naming time in the baseline control condition to the Critical-6 condition and then to the Critical-12 condition. With successful inhibition, the target item would be no more distracting than an unrelated item. This would be evident by finding no difference in naming times between the baseline control condition and either the Critical-6 or Critical-12 conditions. On the other hand, if the target item is

being strongly activated and unsuccessfully inhibited, then it will be more difficult to ignore than an unrelated item. This would increase the naming time in the Critical-6 and Critical-12 conditions compared to the baseline control condition.

Interference and Recognition Accuracy

Comparing the young adults and older adults on recognition performance the following predictions were made to address the age-related differences in recognition accuracy in each of the four treatment conditions. In the no distractor condition we expected an age difference favoring the young adults (Balota et al., 1999; Norman & Schacter, 1997; Waldie & Kwong See, in press). The young adults were predicted to correctly recognize more studied items than the older adults, but that this would be reversed for memory of the critical targets. That is, the age effect was expected to be primarily due to the older adults incorrectly remembering more of the critical targets than the young adults. Nevertheless, we expected that the young adults would remain consistently more accurate than the older adults within each condition (see Prull, Gabrieli & Bunge, 2000).

The focus of the subsequent analyses was whether interference altered the pattern of results observed in the no distractor condition. Distracting information was included at study to evaluate the impact of interference on memory accuracy. It was hypothesized that this distraction would make it more difficult for participants to inhibit the activation of irrelevant items. This would be particularly true for older adults if inhibitory control is more problematic for them. This would be reflected in the recognition judgments. We would expect the same pattern of results in the baseline control condition relative to the no distractor condition (with older adults correctly recognizing fewer studied items and

correctly rejecting fewer critical targets than would the young adults). If interference does have an impact on memory accuracy then the absolute size of this crossover effect may be larger in the baseline control condition.

The next question to be addressed is the impact of presenting the critical target as a distractor paired with the sixth studied word (the Critical-6 condition) on recognition performance. If participants are effectively treating the target word the same as any other distractor item and suppressing its processing, then the pattern of age differences in recognition performance would be similar to that seen in the baseline control condition. However, if the target item is not being successfully inhibited and is attracting additional attention at the time of study, then we would predict increased activation of the target item. Being able to access discriminatory information will facilitate identification of the target item as a distractor and improve recognition judgments. Conversely, due to increased activation, the target item may be associated with the studied items in the encoded memory trace without being associated with the discriminatory information needed to determine the context of the target item. This may lead to a sense of familiarity towards the critical targets, without explicit recollection of its presentation as a distractor. An increase in false recognition would support this hypothesis. If presenting the critical target at the end of the list has the same effect on memory performance as does its presentation midway in the list, the predicted outcome in the Critical-12 condition is the same as the Critical-6 condition.

It was expected that the addition of the critical target as interference during study would enable us to simulate the performance of older adults in a population of younger adults. Therefore, in the Critical-6 and Critical-12 conditions, the proportion of false

recognition to critical targets observed with the young adults should become more similar to that seen with the older adults.

Interference and Recognition Response Times

The final assessment measure is the collection of response time data for the recognition task. Previous response time data from the DRM task indicate that participants are as fast to false alarm to critical target items as they are to correctly accept studied items (Tun et al, 1998, but see Brown, Buchanan & Cabeza, 2000). However, response times to correctly rejecting the target items are significantly slower than to incorrectly rejecting studied items (Brown, Buchanan & Cabeza). Consistent with other reports, we expected participants to take equally long to accept as 'old' the studied items and the critical targets. Overall, older adults are expected to exhibit slower response times (Salthouse, 1996). Whether this will vary according to study condition is an empirical question that will highlight the effect of the distractor conditions.

METHODS

Participant Selection and Data Cleaning

Prior to discussion of the participant characteristics, we will review the steps undertaken to exclude all outliers in the data and obtain the final participant sample. The original sample consisted of 42 young adults and 42 older adults. A two-step process was used to remove all invalid data. The first step was to review all individual data points for each participant and remove all erroneous items. Erroneous items were defined as instances when the voice key was not accurately triggered or when the participant did not correctly read the study word. Median values were then calculated for each list word in each condition for the remaining data. For example, the median for word one in each condition was based on the median naming speed for the first word in the five lists, since each participant saw five lists of 12 words in each condition (see below). Due to the above process to remove erroneous data, in some cases fewer than five values were used to calculate the median. Mean and standard deviations for the young adults and the older adults were calculated based on these median values. To ensure that all erroneous data was removed, a second review of the data was completed. At this time participants with a median value greater than 2 standard deviations above or below the mean for any of the 12 list items in the four conditions were removed from further analyses. Overall, these stringent criteria resulted in nine young adults and nine older adults being removed from further analysis. This left 33 participants in each age group.

Participants

The 33 young adults (28 women) and 33 older adults (21 women) volunteered to participate in this experiment. The young adult participants ranged in age from 18 to 41

years (M = 21.06; SD = 4.30) and received course credit in their introductory psychology course for participation. The older adults were recruited from a volunteer pool of community dwelling seniors who regularly participate in research and who are reimbursed for travel. The older adults ranged in age between 64 to 87 years (M = 72.85; SD = 7.08). All participants were English speaking and rated their proficiency with English on a scale of 1 (low) to 7 (high) (young adults: M = 5.89, SD = 1.05; older adults: M = 6.20, SD = .84) as high. All participants gave consent prior to beginning the research project.

The young adults had fewer years of formal education than did the older adults (young adults: M years = 14.00, SD = 0.00, older adults: M years = 15.04, SD = 2.00), t (64) = 2.95, p < .01. The Mill Hill Vocabulary Test (maximum score = 33) was used to estimate current level of crystallized intelligence and indicated that the young adults and older adults did differ (M = 17.58, SD = 3.78 vs. M = 21.45, SD = 3.49, respectively), t (64) = 4.33, p < .01. Rating themselves relative to others their age on a 5-point scale ranging from poor (1) to good (5), the young and older adults did not differ in terms of self-reported health (M = 4.30, SD = .77 vs. M = 4.15, SD = .87, respectively), t (64) = .75, p < .46), or vision (M = 4.21, SD = .89 vs. M = 3.82, SD = .92, respectively), t (64) = 1.77, p < .08). The two groups differed on self-report of hearing (young adults: M = 4.45, SD = .71 vs. older adults: M = 3.27, SD = .94), t (64) = 5.74, p = .00. None of the participants were colorblind.

Materials

The study materials consisted of 35 lists of words counterbalanced so that each participant studied 20 lists (Appendix A). Each of the study lists consisted of the 12

strongest associates to a critical target word and were the same lists normed by Stadler, Roediger and McDermott (1999), with the exclusion of the *army* list. The critical target was never presented as a study item. The four treatment conditions were manipulated within subjects, such that each participant received all four conditions an equal number of times. The amount and type of interference were manipulated across four treatment conditions.

The words for the study phase were presented on a 17-inch computer monitor in bold uppercase Arial font size 24 on a white background. The stimulus items were placed randomly above or below the vertical center of the page, with the distractor item appearing in the opposite location. The study word was identified by color, printed in either red or green. Stimulus items were green and distractors were red for half the participants, whereas the reverse color pattern was true for the other half of the participants.

The no distractor condition sequentially presented the 12 words from the study list alone on the screen (Appendix B, Figure 1). The other three conditions presented pairs of words on the screen and in each case the participant read aloud the study list word and ignored the distractor item. The baseline control condition paired randomly assigned distractor items with each of the studied words (Appendix B, Figure 2). In the Critical-6 and Critical-12 conditions, the distractors were again randomly assigned with the exception of the distractor in position 6 and 12 respectively. In these locations, the critical target word was paired with the studied item (Appendix B, Figures 3 and 4). Each word pair was presented one word above the other separated by a 2 mm space.

Using the 35 list from Stadler, Roediger and McDermott (1999) it was determined that each person would study 5 lists of words in each condition, for a total of 20 lists to be presented for study, with the remaining 15 lists to be used as distractors for the three interference conditions. In total, the 35 lists were counterbalanced into seven sessions so each list appeared an equal number of times in each of the five positions (the four treatment conditions plus as distractors). Duplicate sessions were created to counterbalance for color.

A random number generator was used to determine which session was presented for each participant. Within a session, the order of the list presentation was completely randomized, such that both list order and condition order varied between subjects. All participants within a single study session received a different presentation order for the study lists. The individual study lists were presented in blocked format: all associates were presented together and the order of presentation of words in each list was constant. This ensured that the words within a list were always presented in the order of highest associate to lowest associate.

Regarding the selection of the distractor items, the 15 lists to be used as distractors within each session were pooled and then randomly selected without replacement at run-time to be paired with the stimulus word. These words were randomly selected except for the distractor item in position 6 in the Critical-6 condition and position 12 in the Critical-12 condition. In those two instances, the critical target word matching the study list was inserted as the distractor item.

The recognition list consisted of 100 items: 2 studied items from each list, the critical target item from each list and 40 unrelated non-presented items. The studied items

always consisted of the strongest associate of the target word (i.e., the first word in the study list) and the word from position 8 from the study list (Kensinger & Schacter, 1999; Stadler, Roediger, & McDermott, 1999). The critical words were the 20 target words that were used to generate the studied lists (e.g. needle). The unrelated items were medium to high frequency words (i.e. 11-20 occurrences/million) between three and nine letters in length and were selected from the Celex database (Baayen, Piepenbrock & Gulikers, 1995). All items in the recognition test were randomly presented for each subject and were presented in black Arial font size 24 in the center of the screen.

Procedure

Participants were tested individually. They were instructed to read aloud and remember each of the studied items as quickly but as accurately as possible. The participants read the words aloud into a microphone as they appeared on the screen. Subjects sat 50-60 cm from the monitor with the microphone directly in front of them. The microphone was placed 45 cm away from the computer monitor and approximately 3-5 cm away from the participants' mouth. The visual angle subtended by the distance from the upper edge of the top word to the lower edge of the bottom word (1.6 cm) was between 1.5 degrees and 1.8 degrees.

A practice trial of 12 words was administered prior to beginning the experiment to ensure the participants were comfortable with the microphone and to confirm the microphone was recording their responses. On occasion the practice trial was repeated to confirm that the microphone would reliably record the voice response. The participants were instructed that if their response was not detected by the microphone they needed to

repeat the word as quickly as possible. It was emphasized that they should try to minimize this. The experimenter recorded errors in naming and voice key failures.

In each experimental trial the participants were read the instructions and given an opportunity to ask questions. The trial began with a centered question mark displayed for 5 seconds prior to the presentation of the first word. As soon as the microphone detected the voice response, the words disappeared from the screen and were replaced with a centered fixation cross. The fixation cross was displayed for 1.5 seconds after each word. Although this format resulted in unequal presentation time for each word and each subject, this procedure was used to provide young and older adults the opportunity to fully process the information. Because older adults are hypothesized to process information more slowly than younger adults (Salthouse, 1996), a predetermined presentation duration maybe either be insufficient for the older adults to fully process the information, or may give the young adults an unfair advantage of extra processing time. In having the word disappear as soon as it was read aloud, we equated the amount of time needed to respond appropriately for the word.

Between each list of words a question mark was presented for five seconds. Following the presentation of the final list the participants completed an unrelated filler task for three minutes, prior to completing the recognition test. After three minutes the participants were given instructions for the recognition task in which they were told to indicate 'yes' if the word displayed was an old word (previously studied) or 'no' if it was not a previously studied word (a new word). The participants responded with key presses on a response box connected to the computer. The 'yes' response was the left most key and the 'no' response was the right most key. The recognition test was self-paced, though

participants were instructed to respond as soon as they knew the answer. Both response choices and response times were recorded for the recognition test. Including debriefing at the end of the session, sessions took between 30 and 40 minutes.

RESULTS

The three aspects of the study design will be discussed sequentially such that the results of the recognition task will be presented first, followed by presentation of the naming time results and concluding with the recognition response time results. Within each section the effect of age will be examined by comparing the young adults to the older adults. To determine the presence of the false memory effect in the recognition task we will compare the proportion of 'old' judgments to studied items to the proportion of 'old' judgments to the critical targets. The effect of study condition will be addressed within each section with planned comparisons targeting our specific research hypotheses rather than exploration of the omnibus F Test (Keppel & Zedeck, 1989). Effects are significant at the $p \leq .05$ unless otherwise specified.

Interference and Recognition Accuracy

With regard to recognition memory performance we were interested in documenting age-related differences in susceptibility to false memory errors within each treatment condition. The second question of interest would then be whether the pattern of the false memory effect varied between conditions. To address age differences in recognition memory for the critical target (false alarms) as a function of correct responses to studied items (hits), we calculated the mean proportion of 'old' responses of each item type (studied items and critical targets), within each age group and each study condition. For example, for the list of associates to the word ***needle***, correct recognition of a studied item would be responding old to *thread.* A false alarm to a critical target would be responding old to ***needle***. Table 1 displays the proportion of studied and critical target items identified as 'old' by the two age groups within each condition.

Insert Table 1 about here.

We begin by looking for evidence of an age difference in susceptibility to false memory errors in the no distractor condition, as has been documented elsewhere (Balota et al., 1999, Norman & Schacter, 1997). A two-way mixed-factor ANOVA that included item-type (2: studied item, critical target) as within-subject factors and age (2: young, older adults) as between subject factor on the responses in the no distractor condition (Table 1, column 1) was performed to address this question. The significant main effect of age, $F(1,64) = 5.34$, $MSE = 5.28 \times 10^{-2}$ and the marginally significant item-type effect, $F(1, 64) = 3.62$, $MSE = 3.87 \times 10^{-2}$ were qualified by a significant age X item-type interaction, $F(1, 64) = 5.09$, $MSE = 3.87 \times 10^{-2}$. This interaction shows that, as expected, the older adults were more susceptible to false memory errors. That is, the older adults recognized as many studied items as the young adults but falsely recognized more critical target than did the young adults.

To identify the impact of distraction on this age-related susceptibility to false memory errors, we focused on recognition performance in the baseline control condition (Table 1, column 2 from the left). A two-way repeated measure ANOVA conducted on the baseline control data with item-type (2: studied item, critical target) as within-subject factors and age (2: young, older adults) as between-subject factor indicated that the significant main effect of item-type, $F(1,64) = 4.24$, $MSE = 3.01 \times 10^{-2}$ was qualified by a significant age X item-type interaction $F(1,64) = 5.10$, $MSE = 3.01 \times 10^{-2}$. There was no effect of age, $F(1, 64) = 1.67$, $MSE = 6.92 \times 10^{-2}$. Although studied items were

remembered better than the critical targets in general, the young adults were more accurate in rejecting the critical targets than were the older adults. This is similar to the results of the no distractor condition.

Did pairing the critical target as a distractor to the sixth studied item have an impact recognition memory? To address this question a 2 (age: young, older adults) X 2 (item-type: studied items, critical target) repeated measures ANOVA was conducted targeting the results of the Critical-6 condition (Table 1, column 3 from the left). Interestingly, there was a significant main effect of item-type, $F(1,64) = 4.58$, $MSE = 3.35 \text{ X } 10^{-2}$ but no effect of age $F(1,64) = .25$, $MSE = 6.79 \text{ X } 10^{-2}$ and no interaction $F(1,64) = 1.41$, $MSE = 3.35 \text{ X } 10^{-2}$. Presentation of the critical target as a distractor in the sixth list position appears to be associated with a reduction in the age-related false memory effect due to an increase in the proportion of false alarms made by the young adults. Although there is still a trend for the older adults to make more false memory errors than the younger adults, the interaction fails to reach significance in this condition.

Having demonstrated reduced age-related susceptibility to false memory errors associated with presenting the critical target in the sixth position, we were interested in whether this same effect was apparent when the critical target was paired with the twelfth list word. Once again a 2 (age: young, older adults) X 2 (item-type: studied, critical target) was conducted, this time targeting the data from the Critical-12 condition (Table 1, column 4). Importantly, this analysis revealed a significant age X item-type interaction, $F(1, 64) = 7.04$, $MSE = 3.87 \text{ X } 10^{-2}$ but no significant main effects of age, $F(1,64) = 2.54$, $MSE = 6.86 \text{ X } 10^{-2}$ or item-type, $F(1,64) = 2.83$, $MSE = 3.87 \text{ X } 10^{-2}$. Therefore, similar to both the no distraction and baseline control conditions, presenting the critical

target in the twelfth position is associated with an age-related susceptibility to false memory errors. The younger adults correctly recognized as many studied items as the older adults but made fewer erroneous responses to the critical targets than did the older adults.

Also included in the recognition task were 40 items that were not presented at study and were completely unrelated to the study items. False alarms to these items were relatively low for both young and older adults ($M = .09$, $SD = .08$ and $M = .18$, $SD = .13$, respectively). Comparison of these values with the proportion of false alarms to critical targets for both age groups in each condition indicated that both young and older adults made significantly fewer false alarms to unrelated items than to the critical targets (all t's > 10.31).

Recognition accuracy summary. The results of the recognition task indicate that the older adults were more likely to incorrectly accept the critical targets as studied items than were the young adults. This pattern was evident in the no distractor condition, the baseline control condition and the Critical-12 condition. Importantly, when the critical target was paired with the sixth list word, the memory performance of the young adults became less accurate. In other words, their memory performance became more similar to the older adults. Evaluation of naming times will now examine whether this same pattern is evident during on-line processing.

Interference and Naming Times

Demonstration of the false memory effect in the recognition task provides a basis from which to explore our next research question: can the underlying processes of this false memory effect be highlighted by quantification of online processing? To address

this question the naming times of young adults and older adults were analyzed in a series of planned comparisons targeting specific between condition comparisons to reveal age-related processing differences.

The first analysis was to identify if older adults' naming speed was differentially affected by distraction compared to young adults. The total list naming times used for this analysis were calculated by summing the median values for the 12 list items for each participant within each of the four conditions. The mean and standard deviations for each age group were then calculated (Table 2). To identify the impact of distraction an ANOVA with age (2:young, older adults) as a between-subjects factor and condition (2: no distractor, baseline control) as the within-subjects factor was performed. This analysis revealed significant main effects of age, $F(1,64) = 43.56$, $MSE = 8.76 \text{ X } 10^5$ and condition, $F(1, 64) = 458.39$, $MSE = 8.43 \text{ X } 10^4$ as well as a significant age X condition interaction, $F(1, 64) = 5.25$, $MSE = 8.43 \text{ X } 10^4$. As is evidenced by inspection of the two left-hand columns of Table 2, the older adults took significantly longer to read the list items than did the younger adults and were particularly slowed by distraction.

Insert Table 2 about here.

In the recognition analysis of the Critical-6 condition, the young adults performed more like the older adults. Will this also be evident in on-line processing when the critical target is paired with the sixth list word as a distractor? Two repeated measure ANOVA's addressed this question. The dependent variable for the first ANOVA was the naming time for the sixth list item in the two conditions. This item was selected because the

critical target was the distractor in this position in the Critical-6 condition (Table 3). This ANOVA, which included age (2:young, older adults) as the between-subjects factor and condition (2: baseline control, Critical-6) as the within-subjects factor revealed only a significant main effect of age, $F(1, 64) = 33.53$, $MSE = 9.31 \times 10^3$ but no effect of condition, $F(1, 64) = .01$, $MSE = 4.76 \times 10^3$, and no interaction, $F(1, 64) = .01$, $MSE = 4.76 \times 10^3$. The older adults took longer than the younger adults to read the word presented in the sixth list position but neither group were specifically slowed by presentation of the critical target compared to an unrelated target.

Insert Table 3 about here.

The second analysis, using the total word naming times as the dependent variable, was an ANOVA with age (2:young, older adults) as a between-subjects factor and condition (2: baseline control, Critical-6) as the within-subjects factor (columns 2 and 3 of Table 2). The main effects of age, $F(1, 64) = 47.78$, $MSE = 8.77 \times 10^5$ and condition, $F(1, 64) = 7.40$, $MSE = 6.52 \times 10^4$ were significant but there was no interaction between the two, $F(1, 64) = 2.06$, $MSE = 6.52 \times 10^4$. The young adults were able to name the words more quickly than the older adults in both conditions. Importantly, both age groups were able to name the list of words in the Critical-6 condition more quickly than in the baseline control condition. This may indicate that presentation of the critical target as a distractor may impact the speed of naming for items following its presentation.

To explore this possibility, we calculated the total naming times for the list items in the second half of the baseline control condition and the Critical-6 condition (items 7 –

11). An ANOVA with age (2: young, older adults) and condition (2: baseline control, Critical-6) as the independent variables provides partial support for this hypothesis. The significant main effects of condition, $F(1, 64) = 10.83$, $MSE = 1.72 \text{ X } 10^4$ and age, $F(1, 64) = 40.95$, $MSE = 1.67 \text{ X } 10^5$ were qualified by a significant age X condition interaction, $F(1, 64) = 4.14$, $MSE = 1.72 \text{ X } 10^4$. The condition effect suggests that items from the bottom half of lists in the Critical-6 condition were read faster than those in the baseline control condition ($M = 3154.81$, $SD = 37.71$; $M = 3079.78$, $SD = 37.04$, respectively). However, this effect was primarily evidenced with the older adults in the Critical-6 condition (older adults: $M = 3284.33$, $SD = 360.55$; young adults: $M = 2875.23$, $SD = 225.99$).

The final set of analyses regarding naming speed examines the impact of having presented the critical target with the 12th list word. Similar to the above analysis two separate ANOVA's were conducted, targeting first the naming time for the 12th word and then looking at the total naming times in the two conditions. Entering word naming speed of only the 12th list word into a 2 (age: young, older adults) X 2 (condition: baseline control, Critical-12) ANOVA revealed only a significant main effect of age, $F(1, 64) = 23.80$, $MSE = 9.67 \text{ X } 10^3$, with no condition effect, $F(1, 64) = 1.31$, $MSE = 3.70 \text{ X } 10^3$ and no interaction, $F(1, 64) = .17$, $MSE = 3.70 \text{ X } 10^3$. As can be seen by inspection of the right half of Table 3 the older adults consistently took longer to name the presented words than did the young adults. Regarding the total naming times (Table 2), a 2 (age: young, older adults) X 2 (condition: baseline control, Critical-12) ANOVA revealed this same pattern of results. That is, a significant main effect of age, $F(1, 64) = 43.27$, $MSE = 9.99 \text{ X } 10^5$, with no condition effect, $F(1, 64) = 1.90$, $MSE = 5.64 \text{ X } 10^4$ and no

interaction, $F(1, 64) = 1.25$, $MSE = 5.64 \text{ X } 10^4$ confirmed that the older adults took longer to name the presented items, but were not specifically slowed by the distractor item. Because of the null effect of condition, the analysis on only the second half of this list, as was done in the Critical-6 condition, was not repeated.

As a post-hoc analysis, we revisited the percentage of naming errors generated by the young and older adults. In order that participants with no errors would not be excluded we calculated and analyzed the percent correct rather than the percent of naming errors. The number of times a participant incorrectly read the distractor item was subtracted from the total number of words read by each participant (240 words). This was then converted into a percentage. The young adults were very accurate, naming the distractor item only .43% of the time (percent correct $M = 99.57$, $SD = .54$). Even though the older adults were also very accurate (percent correct $M = 98.94$, $SD = 1.47$) they were significantly more likely to name the distractor item than were the young adults, $t(64) = 2.32$.

Naming time summary. The older adults consistently took longer to name the presented words, and were particularly slowed by the addition of distracting information. Although presentation of the critical target did not have specific impact on naming speed for the 6th or 12th word items (in the respective conditions), there was an effect on the total list naming time when the critical target had been presented in the 6th position. Both the young and older adults read the list of words in the Critical-6 condition faster than the baseline control condition, an effect that was not seen in the Critical-12 condition. Subsequent analysis suggested that presentation of the critical target as a distractor may impact the speed of naming for items following its presentation, at least for the older

adults. If this is indeed the case, then an effect would not be expected in the Critical-12 condition since the critical target is presented at the end of the list.

Interference and Recognition Response Time

The final research question addresses the effect of age on recognition response times within the four treatment conditions and item types. The dependent variables were the mean response times to judge studied items and critical targets as 'old' (referred to as hits and false alarms, respectively). The number of subjects included in each analysis varied because not all participants made each response type.

Table 4 displays the mean response times for hits and false alarms for each age group. To investigate whether there is an age-related difference in time to respond to the recognition items a 2 (age: young, older adults) X 2 (item-type: hits, false alarms) repeated measures ANOVA was conducted using only the response times from the no distractor condition (Table 4, column 1). This analysis revealed only a marginally significant main effect of age, $F(1, 63) = 3.48$, $MSE = 3.20 \text{ X } 10^5$ and no item-type effect, $F(1, 63) = .03$, $MSE = 9.69 \text{ X } 10^4$ and no significant interaction, $F(1, 63) = 1.60$, $MSE = 9.69 \text{ X } 10^4$. Although there was a trend for the older adults to take longer than the younger adults to respond overall, within each age group participants were equally fast to make 'old' judgments to the studied items and the critical targets.

Insert Table 4 about here.

Response times in the baseline control condition were selected to assess the effect of general distraction at study on recognition response times across the two age groups

and two response types. A two-way ANOVA with age (2: young, older adults) as the between-subjects factor and item-type (2: hits, false alarms) as the within-subject factor produced no significant effects of item-type, $F(1, 61) = .03$, $MSE = 1.98 \text{ X } 10^5$, age, $F(1, 61) = .54$, $MSE = 3.14 \text{ X } 10^5$, or the interaction, $F(1, 61) = 1.60$, $MSE = 1.98 \text{ X } 10^5$.

Considering that presentation of the critical target paired with the sixth list item affected recognition accuracy performance, we were interested in whether this pairing would also impact response time measures. A two-way ANOVA with age (young, older adults) as the between-subjects factor and item-type (hits, false alarms) as the within-subjects factor performed on the Critical-6 condition revealed a significant item-type effect, $F(1, 63) = 4.54$, $MSE = 2.16 \text{ X } 10^5$ but no age effect, $F(1, 63) = 1.19$, $MSE = 4.13 \text{ X } 10^5$ and no interaction, $F(1, 63) = .50$, $MSE = 2.16 \text{ X } 10^5$. Inspection of columns 2 and 3 in Table 4 indicates that having seen the critical target as a distractor at time of studied slowed the judgment of these critical targets as 'old' ($M = 1413.41$) compared to the judging studied items as 'old' ($M = 1281.52$).

To identify whether presenting the critical target as a distractor paired with the 12^{th} studied word also impacted response times we looked at the Critical-12 condition. Similar to the baseline control condition, a 2 (age: young, older adults) X 2 (item-type: hits, false alarms) repeated measures ANOVA produced no significant effects of item-type, $F(1, 63) = 2.56$, $MSE = 2.21 \text{ X } 10^5$, age, $F(1, 63) < .01$, $MSE = 4.72 \text{ X } 10^5$, or interaction, $F(1, 63) = 2.58$, $MSE = 2.21 \text{ X } 10^5$. There was no difference between the young adults and the older adults in the length of time to respond correctly to studied items and to incorrectly accept the critical targets.

Recognition response time summary. Analysis of response times to judge studied items and critical targets as 'old' indicates that in three of the four conditions both young and older adults were equally fast in their judgments of the studied items and critical targets. However, both young and older adults were significantly slower in responding to the critical targets in the Critical-6 condition than responding to the studied items. It appears that both groups were less confident in judging the critical target as 'old' when they had previously experienced it as a distractor mid-way through list presentation.

DISCUSSION

The goal of this experiment was to better understand age-related increases in false memory errors. This was accomplished by specifically evaluating the impact of interference at time of study on later memory accuracy. To this end, distractor words were presented with the to-be-studied lists. Three behavioral measures (recognition accuracy, naming times and recognition response times) were included to assess the impact of the distraction.

Age Differences, Interference and Recognition Accuracy

The recognition task confirmed the existence of the false memory effect, with both younger and older adults incorrectly accepting, with high probability, the critical target (Roediger & McDermott, 1995). Furthermore, the age-related increased susceptibility to false memory errors was evident in three of the four experimental conditions. That is, the older adults were more likely to incorrectly report having seen the non-presented critical target items than were the young adults (Norman & Schacter, 1997; Waldie & Kwong See, in press). In particular, pairing the critical target with the sixth list word negated the age-related false memory effect. This finding was largely attributed to the reduced accuracy of the young adults.

Age Differences, Interference and Naming Times

The younger adults were significantly faster to name the presented words than were the older adults across all conditions. This is consistent with the general cognitive slowing model (Salthouse, 1996). In addition, inclusion of unrelated distractors differentially increased word-naming time for the older adults (cf. McDowd & Oseas-Kreger, 1991; Tipper, 1991). Presentation of the critical target as the distractor of the

sixth studied word facilitated total list naming times for the younger and older adults. This effect was not evident when the critical target was paired with the 12th list item. Subsequent analysis suggested that the impact of the critical target might be on the speed of word naming for items following its presentation, at least for the older adults.

Age Differences, Interference and Recognition Response Times

The final set of analyses targeted the length of time needed to judge the studied items and the critical targets as 'old' (or items they had read aloud). Once again, the results of the Critical-6 condition are exceptional. In this condition, young and older adults took significantly longer to respond to the critical targets than to the studied items. In contrast, the time needed to judge the studied items and critical targets as 'old' was equally fast in the other three conditions. Response times have been found to correlate strongly with fluency in accessing information and confidence in one's responses (Robinson, Johnson, & Herndon, 1997). For example, longer response times may signify reduced confidence with one's response. According to this view, the relatively fast response time across most of the items suggests that the younger and older adults were relatively confident with their responses. Alternatively, it may be interpreted that the diagnostic information used to make the judgments was readily accessible. As indicated above, the one exception was in responding to the critical targets when they had been presented as distractors in the sixth position. In that case, the longer response times exhibited by both groups suggests that diagnostic information was not as readily accessible, or that the participants were less confident in their response and contemplated their answer prior to responding.

Implications for the DRM Paradigm

This experiment investigated susceptibility to false memory errors in young and older adults, and the impact of presenting interference on retrieval accuracy. Converging evidence indicates that presentation of the critical target as a distractor mid-way through the study list impacted performance, such that the young adults' responses became more similar to the older adults' in a subsequent memory test. On the basis of these results we will explore an interpretation within the inhibitory deficit framework and discuss the implications of this work for understanding the mechanisms underlying age-related increased false memory errors.

According to the inhibitory deficit theory, efficient inhibitory control mechanisms constrain the contents of working memory to those most relevant to the current task (Hasher & Zacks, 1988, Hasher et al., 1999). It further states that as a result of the aging process, these inhibitory control mechanisms become less efficient thereby increasing the likelihood that non-goal relevant information will be processed in working memory. As a consequence, older adults show deficits on immediate comprehension or online processing as well as 'downstream' retrieval tasks, such as occurs in this study.

Focussing first on the recognition performance of the older adults, the consistent pattern of recognition accuracy across the four conditions suggests that the memory experiences of the studied items and critical targets were indistinguishable. Failing to demonstrate fluctuations in the false memory effect between conditions may reflect reduced ability to suppress non-goal relevant thoughts during the study phase. For example, in as much as the design of the DRM paradigm promotes the automatic spread of activation between semantically related list items, the critical target will become

highly activated or primed. Inability to effectively suppress these internally generated but spurious thoughts of the critical target at study may lead to these items becoming encoded in the memory trace along with the actual studied items. Older adults typically experience difficulty in determining the source of retrieved memories and therefore discriminating between read and self-generated thoughts would likely be a challenging task (Spencer & Raz, 1995). If this were the case, then explicit presentation of the critical target in the interference conditions may not be expected to pose additional difficulties.

In contrast, if we assume that internally generated thoughts are less problematic for young adults, then external interference may have relatively more impact on their performance (Zacks & Hasher, 1997; Burke, 1997). We hypothesized therefore, that explicit presentation raised the level of activation of the critical target beyond a baseline threshold level for the young adults so that it too became encoded in the memory trace. The end result for both groups was heightened ambiguity in critically evaluating their memorial experience when presented with the critical target at test. This ambiguity was evident in the increased response latencies to the critical target in the Critical-6 condition. The older adults experienced difficulty discriminating between read and self-generated items, whereas the younger adults had difficulty discriminating between whether the item was read as a studied item or as a distractor item. On the other hand, the ability to activate task-relevant items in working memory appears to have remained the same across age (Zacks & Hasher, 1997). Not only were the two groups similar in their correct responses to studied items, but also they were equally fast in making these same judgments.

Review of the literature supports this rationale. For example, in a garden-path sentence task, in which participants must remember the sentence ending provided by the

experimenter instead of a self-generated and highly probable sentence ending, older adults typically have more difficulty inhibiting the highly probable sentence item compared to the young adults. Similar to the present findings, once these internally generated target items gained access to working memory the older adults were less efficient at suppressing or deleting them (Hartman & Hasher, 1991; Hasher & Zacks, 1999). Moreover, the increased number of activated items may compromise veridical memory because of increasing competition at encoding and retrieval similar to that seen in the fan effect or tasks that divide attention at encoding (e.g. Anderson, Craik, & Naveh-Benjamin, 1998; Gerard et al., 1991).

Supporting evidence that the self-generated critical target may have become strongly activated is derived from the semantic priming literature, in which older adults typically show hyperpriming effects relative to young adults. Specifically, young and older adults respond more quickly and accurately in lexical decision tasks when a target word is semantically related to the preceding item compared with when it is a semantically unrelated item. Importantly, the difference between the two conditions is greater in older adults (Laver & Burke, 1993). Therefore, even following a single word presentation the spread of activation to related items is stronger, or less inhibited with increasing age.

Finding an effect of presenting the critical target as a distractor in the Critical-6 condition and not in the Critical-12 condition may also be related to the well-documented serial position effect (Glanzer & Cunitz, 1966). Typically, items at the beginning and end of lists are remembered better than the medially presented items. In keeping with this, pairing the critical target with a studied item at the end of the list with items that have a

higher probability of being remembered perhaps served as a diagnostic cue to its occurrence as a distractor. This would further indicate that although interference may underlie the age difference in false memory errors, monitoring difficulties are also paramount.

More support for the proposed explanation as to the underlying mechanisms of the increased susceptibility to the false memory effect with increasing age arises directly from examination of the study phase naming times. These provided an online index of the degree of interference as well as support for the rationale presented above. We proposed that older adults may be less able to inhibit activation of non-goal relevant thoughts during the study phase. The disproportionate increase in naming times in the presence of distraction for older relative to younger adults supports this hypothesis that interference was more problematic for the older adults. Finding that the older adults also made more naming errors is also consistent with the notion that they were less able to successfully ignore the distractor item. This is in keeping with a large body of work documenting age differences to interference (Tipper, 1991). For example, older adults are significantly slower to identify a target picture accompanied by a distracting picture than if the target picture was paired with an abstract shape. The difference between the two conditions was greater for the older adults than it was for the young adults.

Based on finding increased naming times we inferred that more lexical items entered working memory space. We propose that these "extra" items were task-irrelevant stimuli. Logically, increased items in working memory space will effect the encoding of these items in the stored memory trace. For example, according to memory-based theories (e.g. Hintzman, 1988; Logan & Etherton, 1994), co-occurring events are stored

together in the memory trace. Therefore, highly activated thoughts of the critical target in close temporal proximity to the studied items might lead to these events being coincidentally encoded in the memory trace. The result is cluttered (or richer) memory traces (Hasher & Zacks, 1999). The recognition task results discussed previously highlight the consequence of these cluttered memory traces.

Of critical interest in reviewing naming times, is the facilitation seen in the total list naming associated with presentation of the critical target. Comparison of the Critical-6 condition with the baseline control condition highlighted this effect, an effect that was not replicated in the Critical-12 condition. This is a logical pattern of findings assuming that the subsequent studied items were primed by the critical target item. The increased naming times seen with distraction suggest that the distractor item is being processed to some degree. Tipper (1991) argued that distractor items are processed beyond the level of simple feature extraction. If this is true, then activation would automatically spread from this item to related items. This spread of activation would only be readily measurable when the distractor item was closely related to the studied items. This is the case in the Critical-6 condition but not in the other three experimental conditions. Accordingly, one would actually expect to see greater facilitation by the older adults in the last half of the list than the younger adults similar to the hyperpriming effect (Laver & Burke, 1993).

Documentation of a decrease in naming time in the second portion of the list for the young adults in addition to that seen in the older adults would strengthen the above argument. Alternative manipulations in future experiments would substantiate our hypothesis that the critical target is being processed and impacting naming times. For instance, assuming the presentation of the critical target as a distractor is the critical

variable, then decreased word naming times should occur for any items following the target presentation, irrespective of its positioning in the list. We interpret the null effect of the Critical-12 condition as due to the fact that there were no subsequent items to see an effect. Presenting additional words (i.e. making the study list longer) but still presenting the critical target as the 6th and 12th list positions may lead to replication of the facilitative pattern seen in the Critical-6 condition.

In summary, the pattern of results seen in this experiment advance our understanding of the mechanisms underlying age-related increases in false memory errors that have been observed in this and other reports. Specifically, these results emphasize the role of inhibitory control in memory accuracy. Decreased naming times associated with the presentation of the critical target, a reduction in the age effect in the recognition task in the Critical-6 condition, and increased response latencies to the critical targets from Critical-6 condition combine to implicate the effect of interference on task performance. Failure to effectively ignore internal interference (for the older adults), or external interference (for the young adults) at study led to monitoring difficulties at test.

Within the false memory literature, this explanation is consistent with dual-processing approaches highlighting both activation and monitoring processes (McDermott & Watson, 2001; Roediger & McDermott, 2000). Based on spreading activation theories (Collins & Loftus, 1975), presentation of the list items leads to converging semantic activation such that the critical target becomes automatically activated at study (Roediger & McDermott, 1995). By this account, the critical target is primed to the point that it is later recognized similar to a studied item. The second component, that of monitoring processes, influences whether this activation becomes a

false memory. In the terms of the Roediger and McDermott framework, "monitoring processes" is a broad term. For example, it includes both source-monitoring framework (Johnson, et al., 1993), and dual-processes of recognition (e.g. Jennings & Jacoby, 1993). To the extent that inhibitory processes are intimately connected to the activation strength of items within the semantic network, the present work provides further support to this framework. By interfering with the activation process and the construction of the memory trace, either by varying the age of participants or through adding distraction at study, we created an environment in which ineffective strategic monitoring processes were utilized.

Limitations and Future Considerations

Although the above rationale for our findings fits within the framework of the inhibitory deficit theory and dual-processing explanations of the false memory effect, stronger empirical effects would have better supported this hypothesis. This may suggest limitations with the theory or may reflect limitations in our experimental design. Naming time measures revealed that the distractor manipulation did in fact differentially impact the older adults. Nevertheless, it may not have been robust enough to negatively impact their performance. Experimental manipulations that intensify the interference, either through overlapping visually presented stimuli or a dichotic-listening task may clarify this possibility. Power calculations further indicated that either stronger manipulations or a larger sample size might have generated more robust findings.

A second possibility for failing to find a strong age-effect regarding the naming/study phase in particular may be consistent with research of the inhibitory deficit theory. Although naming time measurement enables direct quantification of online cognitive processing, offline tasks such as memory measures provide stronger evidence

for the inhibitory deficit theory than do online comprehension measures (Burke, 1997; Zacks & Hasher, 1997). This may be related to the sensitivity of response time measures and to the increased variability in response times within the older adult population.

A third explanation for the failure to find as strong an age-effect as hoped is the selection of our older adult sample. These were individuals who volunteer their time for research projects and may not be representative of the general population. For example, in the current experiment the older adults had achieved higher levels of education than had the young adults. In terms of self-rated health and vision they also rated themselves as high as the young adults did. These variables may be crucial for limiting the impact of interference on daily performance.

One final aspect of the current design that would be important explore in future experiments, would be to further specify how the distractor items impacted performance. This study examined the influence of adding distraction to the study phase of the DRM paradigm. There are two possible interpretations of the effect of such a manipulation on the encoding of information during the study phase. The participants were instructed to read aloud the study item as quickly but as accurately as possible and to remember these study items. Assuming that individuals are limited by a finite set of resources to use to perform this task, the task demands of ignoring the distractor items reduces the resources available with which to encode the study items. As a result, one might expect the episodic trace of the studied items to suffer. That is, due to a lack of resources, the participants may encode fewer features or details associated with the studied items in the memory trace. This would have a negative effect on an individual's ability to recollect specific

details of the study episode to discriminate the studied items from the highly related critical target items.

Alternatively, in attempting to ignore the distractor items, participants may actually encode features of these items into an episodic memory trace. Assuming, as was previously mentioned, that the distractor items are semantically processed, then it may be logical to assume that these items are being at least partially encoded and form even a weak memory trace. In doing this, then the critical target, being a distractor in 2 of the conditions, would have a specific episodic trace associated with it. The presence of this memory trace may also make it more difficult to discriminate between the studied items and the critical targets that had been presented as distractors.

In the present experiment, we were only partially able to separate these two alternatives. The only items in the recognition test that had been presented as distractors were the critical target items. In order to separate which of the above alternatives best accounts for the empirical data, revisions to the recognition test items are needed. For example, the recognition test could be designed such that in addition to the studied items and critical targets, unrelated items presented as distractors and related items not presented as distractors are included. Comparison of unrelated distractor false alarms to critical target false alarms would indicate whether the critical targets are salient because of their associative strength to the studied items or because of an episodic memory trace.

In conclusion, through examination of three behavioral measures we provided evidence that the addition of external interference at study negatively impacted the young adults, such that their performance began to mimic the older adults. Various interpretations of the age-related increased susceptibility to false memory errors have

implicated decreases in source monitoring with age, increased reliance on gist information with age, and also shifting response criteria with age. Although such arguments may partially explain our findings, dual-process approaches implicating both activation and monitoring processes may be more in line with our attempt to understand the factors underlying age-related differences in the false memory errors.

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Table 1

Mean Proportion Recognition Responses by Age Group and Treatment Condition

	Treatment condition							
	No Distractor		Baseline Control		Critical-6		Critical-12	
Item-Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Young adults (n=33)							
Studied item	.74	.17	.66	.19	.74	.19	.71	.23
Non-studied critical target	.59	.76	.53	.26	.64	.27	.56	.27
	Older Adults(n=33)							
Studied item	.75	.17	.65	.20	.73	.21	.69	.19
Critical target	.76	.24	.66	.23	.70	.22	.72	.23

Note. Studied item values are proportion correct responses, critical target values are proportion of false alarms. Each is calculated by dividing the number of each type judged to be old, by the total number of that type of item (40 studied items and 20 critical targets).

Table 2

Overall Mean Word Naming Time by Age Group and Treatment Condition

	Treatment condition							
	No Distractor		Baseline Control		Critical-6		Critical-12	
Age Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young adults	501.63	44.78	582.16	44.93	577.41	39.03	581.27	47.88
Older adults	581.58	63.88	681.41	72.33	666.02	65.72	672.81	71.58

Note. Table represents the average naming time per word within each condition and each age group. Mean word naming times are calculated by dividing the mean total list naming time of all participants in each age group and each condition by the number of items in the studied list (12).

Table 3

Mean Naming Times by Specific List Items by Age Group and Treatment Condition

	Treatment Condition							
	List Word 6				List Word 12			
	Baseline Control		Critical-6		Baseline Control		Critical-12	
Age Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young adults	563.36	55.66	563.11	64.34	584.80	64.19	577.05	70.04
Older adults	659.39	89.04	661.61	113.93	672.65	85.53	656.18	101.92

Note. Table represents the average naming time for word 6 and word 12 in each of the listed conditions within age group. Mean naming times are calculated by selecting only word 6 and 12 in each of the conditions and computing the mean time for all participants in each age group and each condition.

Table 4

Mean Response Times to Hits and False Alarms by Age Group and Treatment Condition

	Treatment condition							
	No Distractor		Baseline Control		Critical-6		Critical-12	
Item-Type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
				Young adults				
Hits	1131.50	305.65	1141.35	307.94	1124.79	311.30	1212.55	446.05
False alarms	1191.64	415.45	1255.31	424.07	1356.47	719.11	1476.74	817.78
				Older Adults				
Hits	1385.70	633.50	1315.12	777.73	1305.65	542.35	1350.49	547.57
False alarms	1307.46	401.74	1228.62	369.37	1421.70	592.40	1350.08	472.81

Note. Hits are correct responses to previously studied items, false alarms are incorrect responses to the non-presented critical target item. Mean response times are in milliseconds. Actual number of subjects in each case varies due to some subjects not having any responses of a particular type in some conditions.

APPENDIX A

Study Lists

ANGER – mad, fear, hate, rage, temper, fury, ire, wrath, happy, fight, hatred, mean

BLACK – white, dark, cat, charred, night, funeral, color, grief, blue, death, ink, bottom

BREAD – butter, food, eat, sandwich, rye, jam, milk, flour, jelly, dough, crust, slice

CAR – truck, bus, train, automobile, vehicle, drive, jeep, Ford, race, keys, garage, highway

CHAIR – table, sit, legs, seat, couch, desk, recliner, sofa, wood, cushion, swivel, stool

CITY – town, crowded, state, capital, streets, subway, country, New York, village, metropolis, big, Chicago

COLD – hot, snow, warm, winter, ice, wet, frigid, chilly, heat, weather, freeze, air

CUP – mug, saucer, tea, measuring, coaster, lid, handle, coffee, straw, goblet, soup, stein

DOCTOR – nurse, sick, lawyer, medicine, health, hospital, dentist, physician, ill, patient, office, stethoscope

FLAG – banner, American, symbol, starts, anthem, stripes, pole, wave, raised, national, checkered, emblem

FOOT – shoe, hand, toe, kick sandals, soccer, yard, walk, ankle, arm, boot, inch

FRUIT – apple, vegetable, orange, kiwi, citrus, ripe, pear, banana, berry, cherry, basket, juice

GIRL – boy, dolls, female, young, dress, pretty, hair, niece, dance, beautiful, cute, date

HIGH – low, clouds, up, tall, tower, jump, above, building, noon, cliff, sky, over

KING – queen, England, crown, prince, George, dictator, palace, throne, chess, rule, subjects, monarch

LION – tiger, circus, jungle, tamer, den, cub, Africa, mane, cage, feline, roar, fierce

MAN – woman, husband, uncle, lady, mouse, male, father, strong, friend, beard, person, handsome

MOUNTAIN – hill, valley, climb, summit, top, molehill, peak, plain, glacier, goat, bike, climber

MUSIC – note, sound, piano, sing, radio, band, melody, horn, concert, instrument, symphony, jazz

NEEDLE – thread, pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection

PEN – pencil, write, fountain, leak, quill, felt, Bic, scribble, crayon, cross, tip, marker

RIVER – water, stream, lake, Mississippi, boat, tide, swim, flow, run, barge, creek, brook

ROUGH – smooth, bumpy, road, tough, sandpaper, jagged, ready, coarse, uneven, riders, rugged, sand

RUBBER – elastic, bounce, gloves, tire, ball, eraser, springy, foam, galoshes, soles, latex, glue

SHIRT – blouse, sleeves, pants, tie, button, shorts, iron, polo, collar, vest, pocket, jersey

SLEEP – bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap

SLOW – fast, lethargic, stop, listless, snail, cautious, delay, traffic, turtle, hesitant, speed, quick

SMELL – nose, breath, sniff, aroma, hear, see, nostril, whiff, scent, reek, stench, fragrance

SMOKE – cigarette, puff, blaze, billows, pollution, ashes, cigar, chimney, fire, tobacco, stink, pipe

SOFT – hard, light, pillow, plush, loud, cotton, fur, touch, fluffy, feather, furry, downy

SPIDER – web, insect, bug, fright, fly, arachnid, crawl, tarantula, poison, bite, creepy, animal

SWEET – sour, candy, sugar, bitter, good, taste, tooth, nice, honey, soda, chocolate, heart

THIEF – steal, robber, crook, burglar, money, cop, bad, robber, jail, gun, villain, crime

TRASH – garbage, waste, can, refuse, sewage, bag, junk, rubbish, sweep, scraps, pile, dump

WINDOW – door, glass, pane, shade, ledge, sill, house, open, curtain, frame, view, breeze

APPENDIX B

Figure B1.Sample image from the no distractor condition. Point is the sixth word in the needle list. Point is printed in red.

Figure B2. Sample image from the baseline control condition. Point is the sixth word in the needle list. Point is printed in red, highway is printed in green.

Figure B3. Sample image from the Critical-6 condition. Point is the sixth word in the needle list. Needle is the critical target. Point is printed in red, needle is printed in green.

Figure B4. Sample image from the Critical-12 condition. Injection is the 12th word in the needle list. Needle is the critical target. Injection is printed in red, needle is printed in green.

No distractor	Baseline control	Critical-6	Critical-12
thread	thread - mouth	thread - mouth	thread - mouth
pin	pin - fast	pin - fast	pin - fast
eye	eye - mug	eye - mug	eye - mug
sewing	sewing - breathe	sewing – breathe	sewing - breathe
sharp	sharp - prince	sharp - prince	sharp - prince
point	point - tamer	point - ***needle***	point - tamer
prick	prick - screen	prick - screen	prick - screen
thimble	thimble - rugged	thimble - rugged	thimble - rugged
haystack	haystack - father	haystack - father	haystack - father
thorn	thorn - state	thorn - state	thorn - state
hurt	hurt - coal	hurt - coal	hurt - coal
injection	injection - melody	injection - melody	injection – ***needle***

Figure B5. Comparison of the four study conditions. Each individual would only see the needle list in one of these conditions, and the distractors would always be randomly selected at run-time of the experiment